CHAPTER 1

FIR FILTERS AND THESIS MOTIVATION

1.1 Introduction to DSP and Filters

Digital Signal Processing (DSP) has a lot of features, algorithms and techniques that makes it better than analog ones. DSP provides flexibility as well as very good performance in terms of attenuation and selectivity. Thus, DSP has a wide use in communication field applications, biomedical engineering, military applications, etc.

One of the most important applications of DSP is the digital filter design. In general, a digital filter presents a system which is used to improve the signal quality and retrieve the desired information from it.

A digital filter has two types: The first is Infinite Impulse Response (IIR) and the second is Finite Impulse Response (FIR) filters. The response of FIR filter when applying an impulse signal at its input will vanish during a finite time. However, IIR filter response to an impulse input never disappears and will extend to infinity. The implementation of FIR filters is further simpler than IIR filters. However, FIR filters are slower than IIR filters. Overall, FIR filters are a preferable choice because they provide stability as well as design simplicity. Thus, in this work we shed the light on the design of FIR filter types using different approaches and evolutionary algorithms.

1.2 FIR Filters Characteristics and Design

FIR filters possess many beautiful properties compared to IIR filters which are guaranteed stability, possibility of exact linear phase characteristic at all frequencies and lower coefficient sensitivity.

There are different methods that are currently used for FIR filters design. Some of these methods are frequency sampling and the windowing. The easiest and popular method is the windowing method.

The widowing method uses many types of window functions such as Butterworth, Chebyshev and Kaiser. The window selection depends on the requirements of the passband and stopband, stopband attenuation, ripples and the transition width. Once the window function is selected ideal impulse response is multiplied with it. The length of the impulse response of ideal filter can be limited by these windows to a finite window to implement the actual response. However, the windowing method doesn't form the optimal design because it suffers from some weaknesses. For example, windowing method is not able to provide sufficient control of the frequency response in the various frequency bands and other filter parameters such as transition width. Filters which are designed by windowing method will have large error on discontinuous sides of the ideal frequency response and frequencies away from the discontinuity will have smaller one [1].

1.3 Related Works

Many methods have been proposed to design FIR filter. One of the most early methods is proposed by Parks and McClellan (PM). This method is the most popular for optimum FIR filter design because of its computational efficiency and its flexibility. PM method can specify the ratio between passband and stopband ripple (δ_p, δ_s). Unfortunately, one cannot determine a specific value for δ_p, neither for δ_s. On the other hand, the floating-point coefficients given by PM which will require quantization if hardware implementation is desired. These reasons lead to develop new optimization algorithms to find optimum taps (or coefficients) of FIR filters. These optimization algorithms, called evolutionary algorithms, will be explored to design optimum FIR

filters with the largest stopband attenuation and better parameters control. The upcoming paragraphs will list some of these algorithms.

Particle swarm optimization (PSO) algorithm was developed by Kennedy and Eberhart in 1995 [4, 5]. PSO can be used as a general optimization method. It is easy to implement and few parameters are used to control it. Some research work has been done in exploring the flexibility of FIR filter design using PSO [6, 8]. PSO algorithm is developed based on social behavior of a swarm of bees, fish schooling and bird flocking and multi-dimensional optimization problems. To improve the efficiency many adjustments of the conventional PSO have been made.

Genetic Algorithm (GA) is another approach which confirms itself to be more efficient from obtaining the local optimum while retaining its moderate computational complexity. Unfortunately, GA was not successful in terms of convergence speed and the quality of the solution [6]. It depends on survival of the fittest concept [10]. Henceforth, GA was described in [13] to design FIR filters. The linear phase is determined by using symmetric filter coefficients. Fixed point implementations are obtained for linear-phase FIR filters by orthogonal GA (OGA) which is based on an experimental design technique in [14]. Stable digital filters with minimum phase for finite impulse response and infinite impulse response is designed by GA in [15].

FIR digital filter design is a subject of interest for researchers in various fields and applications. Many researchers have studied the performance and optimization of FIR filter using different global algorithms.

In [11], the authors described how we can use the PSO algorithm in electromagnetic optimizations. In addition, authors from UCLA present the results that show the swarm behavior in the PSO algorithm.

The authors in [12] studied the effect of Particle Swarm Optimization with Quantum Infusion (PSO-QI) on FIR and IIR filter design. The results show that PSO-IQ has an effect on stopband and passband of the filter response.

Simulated annealing (SA) algorithm is described in [16] to design digital filters with coefficient values which are presented as the sum of a power of two. Linear phase for digital filter procedure by this algorithm is presented. Then the algorithm is applied to design FIR filters.

1.4 Motivation

In this work, we focus our attention on using evolutionary algorithms to design FIR digital filter. These algorithms aim at optimizing the stopband and the passband to have equiripple FIR filters. Fortunately, evolutionary algorithms found to have great importance in filter design compared to traditional algorithms as they provide great improvement of filter response.

In addition, we use one of the most efficient software such as MATLAB to obtain the optimal coefficients of the designated FIR filter. Here, we implement the evolutionary algorithms using such a great software. Furthermore, to verify the obtained results another commercial software called ScopeFIR is used. Afterwards, a comparison between the results obtained via MATLAB and ScopeFIR are compared.

1.5 Problem Statement

Different approaches and techniques both traditional and evolutionary have been used to design FIR filters. Needless to say, most approaches used nowadays are based on evolutionary algorithms. Here, we focus our attention on conducting a comparison between traditional algorithms such as windowing and PM and evolutionary algorithms (PS, PSO, IPSO, SOA, and HSO) in terms of convergence, transition bandwidth and accuracy.

Furthermore, a comparison between the evolutionary algorithms (PS, PSO, IPSO,SOA and HSO) themselves has been performed. As a result, one who is in-charge in designing FIR filters will be able to select one of these algorithm to optimize his design.